भारतीय मानक
Indian Standard

IS 16231 (Part 2) : 2019

भवनों में काँच के प्रयोग — रीति संहिता

भाग 2 ऊर्जा और प्रकाश

(पहला पुनरीक्षण)

Use of Glass in Buildings — Code of Practice

Part 2 Energy and Light

(First Revision)

ICS 81.040.20

© BIS 2019

भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS
मानक भवन, 9 बहादुरशाह ज़फर मार्ग, नई दिल्ली – 110002
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI-110002
www.bis.gov.in www.standardsbis.in

January 2019 **Price Group 10**

Building Construction Practices Sectional Committee, CED 13

FOREWORD

This Indian Standard (Part 2) (First Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Building Construction Practices Sectional Committee had been approved by the Civil Engineering Division Council.

Glazing is an important item in building construction, and glass, the primary glazing element has to be selected to cater to several requirements. Fixing of glass is a specialized operation, when properly done, shall avoid the hazards of broken glass. Growing trend in usage of glazed windows/doors in buildings and structures has considerably increased the importance of glazing and the need for proper workmanship. This standard was, therefore formulated to provide required guidance and provisions on the subject matter.

This Indian Standard is published in four parts. The other parts in this series are:

Part 1	General methodology for selection
Part 3	Fire and loading
Part 4	Safety related to human impact

This standard (Part 2) was first published in 2016 to provide guidance in the selection of glazing in buildings with respect to their effect on energy, visual (light) and solar environments.

Correct selection of materials to be used in glazing for buildings depends on many factors. Therefore, provisions in this standard should be used in conjunction with those in other parts.

Use of organic coated films including safety films on glass (say annealed) shall not classify the glass as safety glass as per this standard, and hence users should exercise caution in choosing their options.

This revision of the standard is aimed at bringing the provisions at par with the provisions of the SP 7 (Part 6/Sec 8) : 2016 ‘National Building Code 2016: Part 6 Structural Design, Section 8 Glass and Glazing’.

In this revision, the following major changes have been made:

a) Provisions related to solar control glass have been updated;
b) Clarification regarding use of low-E glass in double glazed units;
c) Clarification regarding type of spacer used in double glazed units;
d) The window wall ratio (WWR) in the fenestration area has been updated to determine the minimum performance requirement of glazing’
e) Also weather performance namely air infiltration of the glass fenestration has been included; and
f) Definition of various terms have been updated as per the prevailing engineering practice.

In the formulation of this standard, considerable assistance has been derived from the following publications:

ISO 9845-1 (Part 1) : 1992	Solar energy — Reference solar spectral irradiance at the ground at different receiving conditions — Part 1: Direct normal and hemispherical solar irradiance for air mass 1, 5
ISO 10291 : 1994	Glass in building — Determination of steady-state U-values (thermal transmittance) of multiple glazing — Guarded hot plate method
ISO 10292 : 1994	Glass in building — Calculation of steady-state U-values (thermal transmittance) of multiple glazing
ISO 10293 : 1997	Glass in building — Determination of steady-state U-values (thermal transmittance) of multiple glazing — Heat flow metre method

The composition of the Committee responsible for the formulation of this standard is given in Annex D.

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated, expressing the result of a test or analysis shall be rounded off in accordance with IS 2 : 1960 ‘Rules for rounding off numerical values (*revised*)’. The number of significant places retained in the rounded off value should be same as that of the specified value in this standard.

Indian Standard

USE OF GLASS IN BUILDINGS — CODE OF PRACTICE

PART 2 ENERGY AND LIGHT

(First Revision)

1 SCOPE

1.1 This standard (Part 2) covers provisions relating to glazing in buildings with respect to their effect on energy, visual (light) and solar environments in the building.

1.2 This standard does not cover the following:

a) Glazing systems including frameless glazing system, and
b) Patent glazing.

NOTE — The provisions of this standard pertain to selection of glass and associated materials. However, parties, as per their mutual agreement, may appropriately utilize the relevant provisions for installation of alternative sheeting materials used for similar purposes such as plastic glazing sheets/polycarbonate sheets taking also into account requirements of safety issues as applicable with the specific material.

2 REFERENCES

The standards listed in Annex A contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreement based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated in Annex A.

3 APPLICATION

While selecting the glass for application, the type of glass chosen shall satisfy the following criteria:

a) Glazing thickness calculation subjected to wind load is calculated in accordance to IS 16231 (Part 3), and shall satisfy the requirements for human impact safety as per IS 16231 (Part 4); and
b) Installation of glass to the building and selection of glass from their different types, requirements and associated glazing materials, shall be done in accordance with the provisions available in IS 16231 (Part 1).

4 TERMINOLOGY

For the purpose of this standard, the definitions given in IS 14900 and IS 2553 (Part 1), shall apply.

4.1 Coupled Glazing (Also Known as Secondary Glazing) — Two panes of glazing spaced apart in an opening, either in the frame or glazed separately, to form an unsealed cavity.

4.2 Double Glazing — Glazing formed by an assembly of two glass panes separated by a spacer and the gap may be filled by air or inert gases and hermetically sealed along the periphery to improve thermal insulation.

4.3 Edge Deterioration — The discolouration of the reflective coating at the edge of the silvered glass.

4.4 Edge Faults — The faults that affect the as-cut edge of the glass.They may include entrant/emergent faults, shelling, corners on/off and vents.

4.5 Edge Polished — It is usually applied to flat glass, the edges of which have been polished after cutting.

4.6 Fenestration — All area (including frame) in the building envelope that let in light, including window, plastic panels, clerestories, skylight, fanlight and glass doors that are generally more than one-half the floor height, and glass block walls.

4.7 Float Glass — Flat, transparent, clear or tinted soda-lime silicate glass having parallel and polished surfaces obtained by casting and floatation on a metal bath.

NOTE — Flat glass is a general term covering sheet glass, float glass and various forms of rolled and plate glass in which shape of the glass is flat and commonly used for windows, glass doors, transparent walls and other architectural applications.

4.8 Glass — An inorganic non-metallic material produced by the complete fusion of raw materials at high temperature into a homogenous liquid which is then cooled to a rigid condition without crystallizing. It is typically hard and brittle, and has a conchoidal fracture. It may be colourless or tinted and transparent to opaque. The term glass refers to monolithic glass unless specified otherwise.

4.9 Glass Appearance Faults — Faults such as spot and/or linear and/or enlarged area faults which alter the visual quality of glass.

4.10 Glazing — Act of securing of glass or other glazing material into a building in prepared openings in windows, door panels, partitions, etc.

4.11 Hairline Scratch — Very fine scratch that can hardly be seen with naked eye and is associated with glass cleaning techniques.

4.12 Halo — It is the distortion zone around a spot fault.

4.13 Insulating Glass Unit (IGU) — An assembly consisting of at least two panes of glass, separated by one or more spaces, hermetically sealed along the periphery, mechanically stable and durable.

4.14 Interlayer — Layer or material acting as an adhesive and separator between plies of glass and/or plastic glazing sheets.

NOTE — It can be designed to give additional performance to the finished product, for example impact resistance, fire resistance, solar control and acoustic insulation.

4.15 Laminated Safety Glass — It is a glass made of two or more pieces of glass which are held together by an interleaving layer or layers of plastic materials.

4.16 Light Transmission — It is the measure of light passing through a transparent or a translucent material.

4.17 Light Transmittance — It is the measure of percent of visible light transmitted through glass pane which depends on type of body substrate and coating done on glass.

4.18 Linear Defects — They are the scratches and extended spot faults on the glass.

4.19 Modulus of Elasticity (Young's Modulus) — This modulus expresses the tensile force that theoretically has to be applied to a glass specimen to stretch it by an amount equal to its original length. It is expressed as a force per unit area (for glass, $E = 0.7 \times 10^5$ N/mm^2 = 70 GPa).

4.20 Monolithic Glass — A single sheet of flat glass which could be either annealed, toughened or heat strengthened.

4.21 Passive Solar Gain — The solar radiation in the form of energy and light which is transmitted through the glazing into the building and which can be utilized as a source of energy to reduce the need for artificial lighting.

4.22 Reflective Coated Glass — It is a glass with reflective coating which uses the principle of increasing the direct reflection to maximize solar energy attenuation. In comparison with clear glass, its absorption of solar energy is also increased.

NOTE — In comparison with float glass surface, these reflecting coatings (due to their composition) exhibit lower level of emissivity which improves their *U*-value.

4.23 Reflective Silver Coating Faults — It is the fault on reflective silver layer which shall alter the appearance of the silvered glass. It consists of scratches, stains, colour spots and edge deteriorations.

4.24 Shading Coefficient — The ratio of the rate of solar heat gain through a specific unit assembly of glass to the solar heat gain through a single pane of 3 mm clear glass in the same environment.

4.25 Solar Energy Absorption — The percentage of the solar spectrum energy (ultraviolet, visible, and near-infrared) from 300 nm to 2 500 nm that is absorbed by a glass product.

4.26 Solar Energy Transmittance (Direct) — The percentage of energy in the solar spectrum, ultraviolet, visible, and near-infrared energy, 300 nm to 2 500 nm, that is directly transmitted through the glass.

4.27 Solar Heat Gain Coefficient (SHGC) — The SHGC is the fraction of incident solar radiation admitted through a fenestration,both directly transmitted, and absorbed and subsequently released inward through conduction, convection and radiation.

4.28 Spot Faults — The nuclei (solid or gaseous inclusions), deposits, crush marks,etc, in the glass. In certain instances spot faults are accompanied by a distortion zone called 'halo'. The nucleus of the spot fault is measurable.

4.29 Stain — An alteration of the reflective coating characterized by a more or less brownish, yellowish or greyish colouration of zones which can sometimes cover the whole reflective surface.

4.30 Thermal Transmittance (*U*) — Thermal transmission through unit area of the given building unit divided by the temperature difference between the air or other fluid on either side of the building unit in steady state conditions. It is also called as *U*-value. Its unit is W/m^{2}K.

NOTES

1 Thermal transmittance differs from thermal conductance in so far as temperatures are measured on the two surfaces of a building unit in the latter case and in the surrounding air (or other fluid) of the material on the two sides, in the former case. Thermal conductance is a characteristic of the building unit whereas thermal transmittance depends on conductance and surface coefficients of the building unit under the conditions of use.

2 In the case of a glazing system, thermal transmission is taken through the central part of the glass, and thermal conductance of the frame needs to be considered to determine the overall thermal transmission through the glazing system.

3 In the case of a glazing system, thermal transmission is taken through the central part of the glass, and thermal conductance of the frame needs to be considered to determine the overall thermal transmission through the glazing system.

4.31 Tinted Glass — A normal flat glass to which colourants (normally metal oxides) are added during manufacturing process to achieve tinting and solar radiation absorption properties. It is also referred to as body tinted glass.

4.32 UV-Transmittance — The percentage of energy in the ultraviolet (UV) spectrum from 300 nm to 380 nm that is directly transmitted through the glass.

5 ENERGY AND THERMAL PROPERTIES OF GLASS

5.1 General

The energy and thermal properties of glass is defined by light transmission, internal and external reflection, solar heat gain coefficient and *U*-value. The performance requirement for glazing shall be suitably selected. Minimum performance requirement is mentioned in Annex B.

Specific methods of calculating light and energy factors for glass in buildings are covered here and their characteristic data can serve as a basis for light, heating and ventilation calculations of rooms and can permit comparison between different types of glazing. It is applicable to all flat glass material.

5.2 Energy

5.2.1 *General*

Glazed areas in buildings should be designed so that account is taken of the overall energy balance in relation to the effects on the thermal comfort of occupants and the total annual energy implications of solar gain and energy loss.

These should be examined separately, since factors affecting one aspect of performance might have no effect on the other. Energy gain is due to transmission of solar radiant energy through the glass into the building. Solar energy is all at relatively short wavelengths and is controlled by using the glass to absorb or reflect the energy. Energy loss is due to the transfer of energy by conduction, convection and long wavelength radiation and can be influenced by a number of factors, for example incorporating air cavities, including gases of low thermal conductivity and/or low emissivity glass.

5.2.2 *Thermal Comfort*

Energy transmission through glazing can significantly influence occupier comfort by raising or lowering room air temperatures. For example, hot sunny weather can give rise to excessive energy gains; and energy losses can occur through the glazing during cold weather or at night. Thermal comfort can also be influenced by direct radiation through the glazing and/or by radiation exchange between the glazing and the occupants.

5.2.3 *Solar Energy Gain*

Factors that can influence the amount of solar gain through the glazing include:

a) orientation;
b) glazed area;
c) shading devices, both internal and external; and
d) properties of the glazing.

5.2.4 *Total Solar Energy Transmittance*

5.2.4.1 Total solar energy transmittance is the proportion of solar radiation at normal incidence transferred through the glazing. It is composed of the direct transmittance (short wave component) and the part of the solar absorptance dissipated inwards by long wave radiation and convection (long wave component).

The total solar energy transmission properties of solar control glazing can be described by theirshading coefficients. The shading coefficient is derived by comparing the properties of the solar control glazing with a clear float glass having a total solar energy transmittance of 0.87 (that is clear glass between 3 mm and 4 mm thick).

NOTE — Total solar energy transmittance is also known as '*g*' value.

5.2.4.2 *Solar control glass*

a) Solar control glass can be manufactured in several forms. The function of solar control glass is to reduce the total solar energy transmittance, which usually leads to a decrease in the transmission of the visible part of the solar spectrum. However, some tints and coatings are able to attenuate preferentially non-visible solar radiation, leaving the transmission of the greater proportion of the visible radiation largely unchanged.The application of ceramic frit-fired into the surface of the glass can also be used to modify the energy and light transmission of the glass. The effect can be varied across a pane depending on the screen print pattern. Manufacturers should be consulted for specific details.

   Solar control glass can be used in single glazed or double glazed unit depending upon the site requirements. The relationship between light transmission and total solar energy transmission is expressed as the light/energy ratio.

   There is no optimum light/energy ratio. The selection of an appropriate product depends on the requirements of the building. Solar gain may be:

   1) *Relatively high* — For making use of passive solar gains, or

   2) *Low* — To reduce air conditioning loads. Light transmission will depend on the extent to which daylight is used to obviate artificial lighting.

   Some solar control glasses can be toughened or heat strengthened and gives a means of raising the design stress and ensuring safety from thermal fracture.

   NOTE — Some manufacturers use this as a descriptive code, quoting a light transmission figure followed by a total solar energy transmission figure.

b) *Body tinted glass (for increased absorption)* — Solar control properties and colour vary with the thickness of the glass. When used in insulating glass units, body tinted glass should be positioned as the outer pane because the energy due to the absorbed radiation is more easily dissipated to the outside.

c) *Reflective coated glass* — Reflective coated glass uses the principle of increasing the direct reflection to maximize solar energy attenuation. In comparison with clear glass, its absorption of solar energy is also increased. An informative annex on test requirements is given at Annex C.

   The advantages of such glass types are:

   1) Greater performance range than body tinted glass;
   2) Higher performances (greater solar energy attenuation);
   3) Light/energy ratios nearer to the theoretical limit; and
   4) A range of colour appearances in transmission and reflection.

   The coatings may be placed on to body-tinted glass to extend the range of performances.

   NOTES

   1 Compared with a float glass surface, these reflective coatings (owing to their composition)exhibit lower levels of emissivity which improves their *U*-value.

   2 Performance data in comparison to clear glass can be had from manufacturers.

d) *Laminated glass* — Laminated glass is commonly manufactured with clear glass and clear interlayers, but solar control properties can be incorporated into laminated glass by including either solar control glass or tinted interlayers or both.

   Laminated glass with clear interlayers and solar control glass exhibits similar properties to the solar control glass from which it is made.

   Laminated glass with a tinted interlayer acts in a similar manner to body tinted glass, by absorbing the solar radiation, but with a different range of colours and performances.

   NOTE — Performance data in comparison to clear glass can be had from manufacturers. Performances of a typical range of laminated glass products with clear glass and tinted interlayers can be had from manufacturers.

e) *Insulating glass units* — Insulating glass units, that are used primarily for improved thermal transmittance (*U*-value) (*see* **5.3**), can also improve the total solar energy transmittance. This improvement is a result of the incorporation of a second pane of glass together with the hermetically sealed air space. The second glass pane can be of any glass type. The main glasses used as the inner pane are clear glass, hard coat low emissivity glass or soft coat low emissivity glass.

   NOTES

   1 Soft coat low emissivity glass can be used as the hermetically sealed airspace protects the coating.

   2 Performances of a typical range of insulating glass units with clear float inner pane or with hard/soft coat low emissivity glass inner pane can be had from manufacturers.

5.2.4.3 *Solar control plastic glazing sheet materials*

Various coloured plastic glazing sheet materials having ability to reduce the transmission of solar radiation can be used in consultation with the manufacturers.

5.2.4.4 *Blinds and louvres*

The use of blinds or louvres in windows affects the window shading coefficient. This depends upon the solar optical properties of the glazing and the material of the blind, on the coefficients of energy transfer at the window surfaces, on the geometry and location of the blind, and the angular position of the sun. Manufacturers' advice may be consulted for use of these materials.

5.3 Energy Loss

5.3.1 *General*

Energy loss is quantified by the thermal transmittance or *U*-value.

Glass and thin plastic glazing sheet materials readily conduct energy and so are poor insulators. To improve resistance to energy loss, insulating glass units or coupled glazing should be used, since the air cavities provide extra thermal resistance.

Increasing the thickness of the glass or plastic glazing sheet material makes little difference to the *U*-value of the glazing.

5.3.2 *Methods for Improving Thermal Insulation*

5.3.2.1 *Use of low emissivity coatings*

Low emissivity (low-E) coatings have surface emissivities of less than 0.2. The use of such a coating on glass improves the thermal insulation. They are most efficient when used on the cavity surfaces of insulating glass units. Certain types of low-E glasses such as silver based are used in double glazed units only, as the silver oxide coating will get oxidized, if used in single glazed.

5.3.2.2 *Increasing the width of the air space*

Enhanced thermal insulation can be achieved by increasing the width of the airspace. However, there is a convection of the gas in the cavity.

5.3.2.3 *Using gases of lower thermal conductivity*

Replacing the air in the cavity with, for example, argon/krypton, can improve the thermal insulation.

5.3.2.4 *Inhibiting convection within the air space*

Filling the cavity with cellular material reduces convection and makes the cavity a more efficient insulator. However, this usually results in loss of vision, since the materials are, at best, translucent.

5.3.2.5 *Evacuation of the air space*

In theory, a vacuum shall eliminate energy transfer by conduction and convection. However, a vacuum puts high demands on the glass from the external air pressure.

NOTE — 100 percent evacuation of the air space is currently challenging to be technically achieved.

5.3.2.6 *Evaluation of type of spacer used in double glazed unit*

Thermal performance of the glazing system for conduction can be improved by changing the material of the spacer especially when other options have been exhausted.

5.4 Typical *U*-Values of Glass Products

Tables 1, 2 and 3 give typical *U*-Values.

5.5 Thermal Safety of Glass

Thermal safety of glass should be assessed considering the amount of radiation incident on the surface and the thermal capabilities of the glass. For example, the solar radiation intensity on the glass surface should be determined along with the air temperature range applicable to the location of the building. These measurements, together with the energy transfer coefficients and the glass absorption allow determination of the appropriate basic temperature difference between the central area of the glass and its edge. The difference is related to the thermal stress and then modified for the type of glazing system, taking account of extraneous effects resulting from curtains, blinds, back-up walls, proximity to heaters, etc, to derive a stress of actual service conditions.

NOTES

1 High air temperatures, low rates of air movement, and the insulation provided by curtains, blinds, back-up walls and multiple glazing tend to reduce the loss of energy and uphold the centre temperature. Low temperatures at the edges are maintained by conduction from the glass through the frame to a cold building structure with a large thermal capacity.

2 Advice may be sought from the manufacturer of glass as to the methods for assessing the thermal safety of the glass.

The resultant service stress should then be compared with the design stress for the glass. If on comparison, the service stress is less than or equal to the design stress, the glass and glazing system may be accepted as thermally safe provided, that the edges of the glass are of adequate quality.

NOTE — Where the application of a solar control film is being considered to existing glazing, advice should be sought from the manufacturer on the effect of any additional thermal stress likely to be induced in the glass.

Table 1 Thermal Transmittance (*U*-Value) of Glass Products: Single Glazing

(*Clause* 5.4)

Sl No.	**Glass Thickness** mm	***U*-Value** W/m^{2}K
(1)	(2)	(3)
i)	4	5.8
ii)	6	5.7
iii)	10	5.6
iv)	12	5.5

Table 2 Thermal Transmittance (*U*-Value) of Glass Products: Insulating Glass Units

(*Clause* 5.4)

Sl No.	**Clear Glass Thickness and Type** mm	**Cavity Width** mm	***U*-Value** W/m^{2}K	
			Air	Argon
(1)	(2)	(3)	(4)	(5)
i)	4 + 4	6	3.3	3.1
		12	2.9	2.7
		16	2.7	2.6
		20	2.8	2.6
ii)	4 + 4 Low E (ϵ_d = 0.15)	6	2.7	2.3
		12	1.9	1.6
		16	1.7	1.5
		20	1.7	1.5
iii)	4 + 4 Low E (ϵ_d = 0.04)	6	2.5	2.0
		12	1.6	1.3
		16	1.4	1.2
		20	1.4	1.2
iv)	4 + 4 + 4	6	2.4	2.1
		12	1.9	1.8
		16	1.8	1.7
		20	1.8	1.7
v)	4 Low E (ϵ_d = 0.15) + 4 + 4 Low E (ϵ_d = 0.15)	6	1.7	1.4
		12	1.7	1.0
		16	1.0	0.8
		20	0.9	0.8
vi)	4 Low E (ϵ_d = 0.04) + 4 + 4 Low E (ϵ_d = 0.04)	6	1.6	1.2
		12	1.0	0.7
		16	0.8	0.6
		20	0.7	0.6

NOTES

1 *U*-values for argon gas-filled cavity based on 90 percent argon/10 percent air.

2 ϵ_d is the declared (normal) emissivity.

Table 3 Thermal Transmittance (*U*-Value) of Glass Products: Coupled Glazing

(*Clause* 5.4)

Sl No.	Clear Glass Thickness and Type mm	Separation mm	*U*-Value W/m²K
(1)	(2)	(3)	(4)
i)	4 + 4	25	2.8
		75	2.8
ii)	4 + 4 Low E	25	1.7
		75	1.9

NOTE — ϵ_d is the declared (normal) emissivity.

The normal mode of thermal breakage of glass is by the action of tensile stress located in and parallel to an edge, and so the breaking stress of the glass is mainly dependent on the extent and position of flaws in the edges. The condition of the glass edge is therefore extremely important.

Solar control glasses should not be nipped to size and any panes with shelled or vented edges should not be accepted for glazing in orientations subject to direct sunlight. Although a wheel-cut edge is the most satisfactory, laminated glasses with worked edges may be used.

Where clean-cut edges are not permitted, arrises should be created by a wet process, working parallel to the edge and not across the thickness, and the design implications of such an action should be examined.

Where solar control glasses are to be used in sliding doors and windows there is always the possibility that, when opened during sunny periods, the overlapping will function as double glazing with little ventilation in the air space, and it is this condition that should be assumed in assessing the thermal safety of glass.

Thermal safety assessment is based on the behaviour of glass in good condition and properly glazed. Even if the glass is shown to be thermally safe, this depends on close adherence to the recommended glazing procedures. All necessary precautions should be taken to see that only glass with edges of an acceptable condition is used. The glass should be stored and handled so that no contact with hard bodies can damage the edges and each pane or insulating glass unit should be carefully examined immediately before glazing.

5.6 Energy Conservation

Good window design can, by reducing reliance on artificial lighting, can be one of the largest single means of saving energy and should be carefully considered. Consideration should also be made with respect to shape of room, window orientation, occupancy patterns and task, together with the relationship of windows to surrounding buildings and other obstruction. As with task lighting, possible solar overheating might result and similar precautions should be taken.

5.7 Light Transmission Properties of Window

Light transmission is defined as the fraction of visible light at normal incidence transmitted through the glazing. For properties of plastic glazing sheet materials, manufacturers may be consulted.

Dirt on glazing reduces the light transmission, often by an appreciable extent before becoming noticeable. To ensure day lighting levels are adequate, an allowance for the reduced light transmission should be made in day lighting calculation by introducing a ‘dirt factor’between 0.7 and 1.0. Regular cleaning of glass and plastic glazing sheet materials therefore call their importance.

5.8 Glare

5.8.1 *General*

Glare results from excessive contrast of illumination, or from an excess of illumination in the field of view. Reaction to it is subjective. When correctly designed, natural lighting should not be a glare problem.

NOTE — Contrasts in excess of 10 : 1 in illumination in different parts of the field of view might give rise to glare in some form.

5.8.2 *Disability Glare*

Reducing the light transmission of glazing from 87 percent to 60 percent produces a just perceptible reduction in disability glare caused by direct sunlight. Even when the light transmission of the glazing is as low as 10 percent some 10 000 lux can still be experienced and glare shall almost certainly occur.

Glare can be reduced by some form of mechanical shading, for example a canopy, an overhanging floor, a balcony or a louvre system. Alternatively, internal screening can be provided by louvres or blinds.

NOTE — Any fixed shading system reduces the amount of natural light entering the building throughout the year, irrespective of whether there is a glare problem at any particular time.

It may also be possible to re-orientate the glazing to avoid entry of direct solar radiation. Alternatively, the interior layout can be suitably designed to eliminate glare.

5.8.3 *Discomfort Glare*

Glazing products with light transmission lower than 50 percent can ameliorate discomfort glare. These products decrease the sky luminance components but permanently reduce the admission of daylight. Alternatively, shading devices, internal or external, movable or fixed, may be used.

Other methods of reducing the problems of glare should be considered, including:

a) Installation of windows in more than one wall to raise the general background illumination and, in so doing, to reduce the contrast between a window and its surrounding surfaces;
b) Use of light coloured matt finishes for the window frames and the surrounding surfaces;
c) Splayed reveals, to assist in reducing the contrast between the window and its surroundings;
d) Use of slender glazing bars and transoms of high reflectance;
e) Lowering window sills to allow increased illumination to enter, which increases the adaptation level and reduces the likelihood of discomfort glare; and
f) Providing windows in walls considering their orientation.

5.9 Diffusion and Obscuration

The nature of some glazing products (for example, patterned or acid etched glass) can cause the direct incident solar beam to be scattered diffusely. Hence the window might assume an uncomfortable high brightness and become a discomfort glare source in its own right. Diffusing glazing used within the normal field of view should be used with caution.

5.10 Fading

Most materials can fade when subjected to either daylight (particularly direct sunlight) or artificial light. Fading is a complex phenomenon involving many chemical reactions, initiated or accelerated by light of different wavelengths. Generally, the better quality dyes and pigments fade relatively slowly and react only to the shorter wavelengths (ultraviolet and the blue end of the visible spectrum). Other materials can fade quickly and might do so under light of much longer wavelengths. It is the combination of wavelength, available light and transmission which determines glass selection to minimize fading, not simply the UV-transmission.

5.11 Determination of Characteristic Parameters

5.11.1 *General*

The characteristic parameters are determined for quasi-parallel, almost normal radiation incidence.

5.11.2 *Test Set-up*

The samples shall be irradiated by a beam whose axis is at an angle not exceeding 10° from the normal to the surface. The angle between the axis and any ray of the illuminating beam shall not exceed 5°.

The characteristic parameters are as follows:

a) Spectral transmittance $\tau(\lambda)$, the spectral external reflectance $\rho_o(\lambda)$ and the spectral internal reflectance $\rho_i(\lambda)$ in the wavelength range of 300 nm to 2 500 nm;
b) Light transmittance τ_v, the external light reflectance $\rho_{v,0}$ and the internal light reflectance $\rho_{v,i}$ for illuminant D65;
c) Solar direct transmittance τ_e and the solar direct reflectance ρ_e;
d) Total solar energy transmittance (solar heat gain-coefficient SHGC) *g*; and
e) UV-transmittance τ_{UV};

When calculating the characteristic parameters of multiple glazing, the spectral data of each glass component is to be used instead of integrating data of the complete unit.

5.11.3 *Performance Requirements of Optical Measurements*

Optical measurements in transmission and reflection require special care to achieve accuracy in transmittance and reflectance of about ±0.01.

The wavelength calibration and the photometric linearity of commercial spectrophotometers shall be checked periodically using reference materials obtained from metrological laboratories.

The wavelength calibration shall be performed by measuring glass plates which feature relatively sharp absorption bands at specified wavelengths; the photometric linearity shall be checked using grey filters with a certified transmittance.

For reflectance measurements, reference materials having reflection behaviour (that is, reflectance level and ratio of diffuse and direct reflectance).

Thick samples (that is laminated glass or insulating units) can modify the optical path of the instrument's beam as compared to the path in air and therefore the sample beam hits an area of the detector having a different responsivity.

A similar source of inaccuracy occurs in case of samples with significant wedge angles which deflect the transmitted (and reflected) beams. It is recommended to check the reproducibility by repeating the measurement after rotating the sample.

Additionally, in the case of reflectance measurements, glass sheets cause a lateral shear of the beam reflected by the second surface, causing reflectance losses (whose extent is particularly evident in the case of thick and/or wedged samples). This source of inaccuracy shall be taken into account particularly in the case of reflectance measurements through the uncoated side. In order to quantify and correct systematic errors, it is recommended to use calibrated reflectance standards with a thickness similar to the unknown sample.

In the case of diffusing samples (or samples with a non-negligible diffusing component or wedged samples), transmittance and reflectance measurements shall be performed using integrating spheres whose openings are sufficiently large to collect the entire diffusely transmitted or reflected beam. The sphere diameter shall be adequate and the internal surface adequately coated with a highly diffusing reflectance material, so that the internal area can provide the necessary multiple reflections. Reference materials with characteristics similar to the unknown sample as specified above shall be used. If the transmittance or reflectance curve recorded by the spectrometer exhibits a high level of noise for some wavelengths, the values to be considered for those wavelengths should be obtained after a smoothing of the noise.

5.11.4 *Light Transmittance*

Light transmittance is the measure of the amount of light passing through the glazing. The visible light lies between the wavelength 380 nm and 780 nm. The light transmission of the glazing depends on the substrate type and coating layer done on the base glass.

The light transmittance τ_v of glazing shall be calculated using the following formula:

$$\tau_v = \frac{\sum_{\lambda=380\,\text{nm}}^{780\,\text{nm}} \tau(\lambda) D_\lambda V(\lambda) \Delta\lambda}{\sum_{\lambda=380\,\text{nm}}^{780\,\text{nm}} D_\lambda V(\lambda) \Delta\lambda}$$

where

D_λ = relative spectral distribution of illuminant D_{65};

$\tau(\lambda)$ = spectral transmittance of glazing;

$V(\lambda)$ = spectral luminous efficiency for photopic vision defining the standard observer forphotometry; and

$\Delta\lambda$ = wavelength interval.

Table 4 indicates the values for $D_\lambda V(\lambda)\Delta\lambda$ for wavelength intervals of 10 nm. The table has been drawn up in such a way that $\Sigma D_\lambda V(\lambda)\Delta\lambda = 1$.

In the case of multiple glazing, the spectral transmittance $\tau(\lambda)$ shall be obtained by calculation from the spectral characteristics of the individual components. Alternatively, measurements on non-diffusing multiple units may be performed using an integrating sphere. This may be achieved after reducing the interspaces under conditions that allow the collection of the whole transmitted beam.

The calculation of the spectral transmittance $\tau(\lambda)$ shall be performed using methods such as algebraic manipulation. Any algorithm that can be shown to yield consistently the correct solution is acceptable.

For the calculation of $\tau(\lambda)$ as well as for the calculation of spectral reflectance the following symbols for the spectral transmittance and spectral reflectance of the individual components are used:

$\tau_1(\lambda)$ = spectral transmittance of the outer (first) pane;

$\tau_2(\lambda)$ = spectral transmittance of the second pane;

$\tau_n(\lambda)$ = spectral transmittance of the n^{th} (inner) pane (for example, for triple glazing $n = 3$);

$\rho_1(\lambda)$ = spectral reflectance of the outer (first) pane measured, in the direction of incident radiation;

$\rho'_1(\lambda)$ = spectral reflectance of the outer (first) pane measured, in the opposite direction of incident radiation;

$\rho_2(\lambda)$ = spectral reflectance of the second pane measured, in the direction of incident radiation;

$\rho'_2(\lambda)$ = spectral reflectance of the second pane measured, in the opposite direction of incident radiation;

$\rho_n(\lambda)$ = spectral reflectance of the n^{th} (inner) pane measured, in the direction of incident radiation; and

$\rho'_n(\lambda)$ = spectral reflectance of the n^{th} (inner) pane measured, in the opposite direction of incident radiation.

For the spectral transmittance $\tau(\lambda)$ as a function of the spectral characteristics of the individual components of the unit, the following formulae are obtained:

a) For double glazing:

$$\tau(\lambda) = \frac{\tau_1(\lambda)\,\tau_2(\lambda)}{1 - \rho'_1(\lambda)\,\rho_2(\lambda)}$$

b) For triple glazing:

$$\tau(\lambda) = \frac{\tau_1(\lambda)\,\tau_2(\lambda)\,\tau_3(\lambda)}{\left[1 - \rho'_1(\lambda)\,\rho_2(\lambda)\right]\cdot\left[1 - \rho'_2(\lambda)\,\rho_3(\lambda)\right] - \tau_2^2(\lambda)\,\rho'_1(\lambda)\,\rho_3(\lambda)}$$

For multiple glazing with more than three components, relationships similar to above expressions are found to calculate $\tau(\lambda)$ of such glazing from the spectral characteristics of the individual components.

As an example for calculating $\tau(\lambda)$ according to the procedures of this standard, a glazing composed of five components may be treated as follows:

1) First consider the first three components as triple glazing and calculate the spectral characteristics of this combination;

2) Next, run the same procedure for the next two components as double glazing; and
3) Then calculate $\tau(\lambda)$ for the five component glazing, considering it as double glazing consisting of the preceding triple and double glazing.

The light transmission requirement for the glazing should be selected in accordance with relevant Indian Standard.

6 LIGHT REFLECTANCE

6.1 External Light Reflectance of Glazing

External light reflectance corresponds to the amount of sunlight reflected by the external glass surface. The amount of light reflection depends on the type of base glass (substrate tint) and the position of coating on the glass surface.

The external light reflectance of glazing $\rho_{v,o}$ shall be calculated using the following formula:

$$\rho_{v,o}=\frac{\sum_{\lambda=380\,\text{nm}}^{780\,\text{nm}}\rho_o(\lambda)D_\lambda V(\lambda)\Delta\lambda}{\sum_{\lambda=380\,\text{nm}}^{780\,\text{nm}}D_\lambda V(\lambda)\Delta\lambda}$$

where

$\rho_o(\lambda)$ = spectral external reflectance of glazing, and D_λ, $V(\lambda)$, $\Delta\lambda$ and the integration procedure are defined in **5.11.4**.

For multiple glazing, the calculation of the spectral external reflectance $\rho_o(\lambda)$ shall be performed using the same methods as given in **5.11.4** for the calculation of the spectral transmittance $\tau(\lambda)$.

For the spectral external reflectance $\rho_o(\lambda)$ as a function of the spectral characteristics of the individual components of the unit, the following formulae are applied:

a) *For double glazing:*

$$\rho_o(\lambda)=\rho_1(\lambda)+\frac{\tau_1^2(\lambda)\rho_2(\lambda)}{1-\rho_1'(\lambda)\rho_2(\lambda)}$$

b) *For triple glazing:*

$$(\lambda)=\rho_1(\lambda)+\frac{\tau_1^2(\lambda)\rho_2(\lambda)\left[1-\rho_2'(\lambda)\rho_3(\lambda)\right]+\tau_1^2(\lambda)\tau_2^2(\lambda)\rho_3(\lambda)}{\left[1-\rho_1'(\lambda)\rho_2(\lambda)\right]\cdot\left[1-\rho_2'(\lambda)\rho_3(\lambda)\right]-\tau_2^2(\lambda)\rho_1'(\lambda)\rho_3(\lambda)}$$

Table 4 Normalized Relative Spectral Distribution $D_\lambda V(\lambda)\Delta\lambda$

(*Clause* 5.11.4)

Sl No. (1)	λ nm (2)	$D_\lambda V(\lambda)\Delta\lambda$ x 10^2 (3)
i)	380	0
ii)	390	0.000 5
iii)	400	0.003 0
iv)	410	0.0103
v)	420	0.035 2
vi)	430	0.094 8
vii)	440	0.227 4
viii)	450	0.419 2
ix)	460	0.666 3
x)	470	0.985 0
xi)	480	1.518 9
xii)	490	2.133 6
xiii)	500	3.349 1
xiv)	510	5.139 3
xv)	520	7.052 3
xvi)	530	8.799 0
xvii)	540	9.442 7
xviii)	550	9.807 7
xix)	560	9.430 6
xx)	570	8.689 1
xxi)	580	7.899 4
xxii)	590	6.330 6
xxiii)	600	5.354 2
xxiv)	610	4.249 1
xxv)	620	3.150 2
xxvi)	630	2.081 2
xxvii)	640	1.381 0
xxviii)	650	0.807 0
xxix)	660	0.461 2
xxx)	670	0.248 5
xxxi)	680	0.125 5
xxxii)	690	0.053 6
xxxiii)	700	0.027 6
xxxiv)	710	0.014 6
xxxv)	720	0.005 7
xxxvi)	730	0.003 5
xxxvii)	740	0.002 1
xxxviii)	750	0.000 8
xxxix)	760	0.000 1
xxxx)	770	0.000 0
xxxxi)	780	0.000 0

NOTE — Normalized relative spectral distribution D_λ of illuminant D65 multiplied by the spectral luminous efficiency $V(\lambda)$ and by the wavelength interval $\Delta\lambda$. The values in this table are calculated according to the trapezoidal rule.

For multiple glazing with more than three components, relationships similar to above equations are found to calculate $\rho_o(\lambda)$ of such glazing from the spectral characteristics of the individual components.

As an example for calculating $\rho_o(\lambda)$, a glazing composed of five components may be treated in the same way as described in **5.11.4**.

6.2 Internal Light Reflectance of Glazing

Internal light reflectance corresponds to the amount of light reflected by the inner glass surface. The amount of light reflection depends on the type of base glass (substrate tint) and the position of coating on the glass surface.

The internal light reflectance of glazing $\rho_{v,i}$ shall be calculated using the following formula:

$$\rho_{v,i} = \frac{\sum\limits_{\lambda=380\,\text{nm}}^{780\,\text{nm}} \rho_i(\lambda) D_\lambda V(\lambda)\Delta\lambda}{\sum\limits_{\lambda=380\,\text{nm}}^{780\,\text{nm}} D_\lambda V(\lambda)\Delta\lambda}$$

where

$\rho_i(\lambda)$ = spectral internal reflectance of glazing, and D_λ, $V(\lambda)$, $\Delta\lambda$ and the integration procedure are as defined in **5.11.4**.

For multiple glazing, the calculation of the spectral internal reflectance $\rho_i(\lambda)$ shall be performed using the same methods as given in **5.11.4** for the calculation of the spectral transmittance $\tau(\lambda)$.

For the spectral internal reflectance $\rho_i(\lambda)$ as a function of the spectral characteristics of the individual components of the unit, the following formulae are applied.

a) *For double glazing:*

$$\rho_i(\lambda) = \rho_2'(\lambda) + \frac{\tau_2^2(\lambda)\rho_1'(\lambda)}{1-\rho_1'(\lambda)\rho_2(\lambda)}$$

b) *For triple glazing:*

$$\rho_i(\lambda) = \rho_3'(\lambda) + \frac{\tau_3^2(\lambda)\rho_2'(\lambda)\left[1-\rho_2(\lambda)\rho_1'(\lambda)\right] + \tau_3^2(\lambda)\tau_2^2(\lambda)\rho_1'(\lambda)}{\left[1-\rho_3(\lambda)\rho_2'(\lambda)\right]\cdot\left[1-\rho_2(\lambda)\rho_1'(\lambda)\right] - \tau_2^2(\lambda)\rho_3(\lambda)\rho_1'(\lambda)}$$

For multiple glazing with more than three components, relationships similar to above expressions are found to calculate $\rho_i(\lambda)$ of such glazing from the spectral characteristics of the individual components.

7 TOTAL SOLAR ENERGY TRANSMITTANCE (SOLAR HEAT GAIN COEFFICIENT)

7.1 Solar heat gain coefficient (SHGC)/solar factor (SF) is the measure of amount of heat transfer from outside to inside by direct transmission (Short Wave Radiation) and internal remitted radiation (Long Wave Radiation). The SHGC (*see* Fig. 1) or SF depends on the tint of the substrate and also the type of coating that is done on the base glass. The amount of solar energy gained through glass is between 0 and 1. Multiplying the SHGC or SF by 100 gives the percentage of solar energy allowed into the building.

The total solar energy transmittance g is the sum of the solar direct transmittance τ_e and the secondary heat transfer factor q_i towards the inside, the latter resulting from heat transfer by convection and long-wave IR-radiation of that part of the incident solar radiation which has been absorbed by the glazing and is expressed as:

$$g = \tau_e + q_i$$

7.2 Division of Incident Solar Radiation Flux

The incident solar radiant flux per unit area φ_e is divided into the following three parts (*see* Fig. 2):

a) Transmitted part, $\tau_e\varphi_e$;

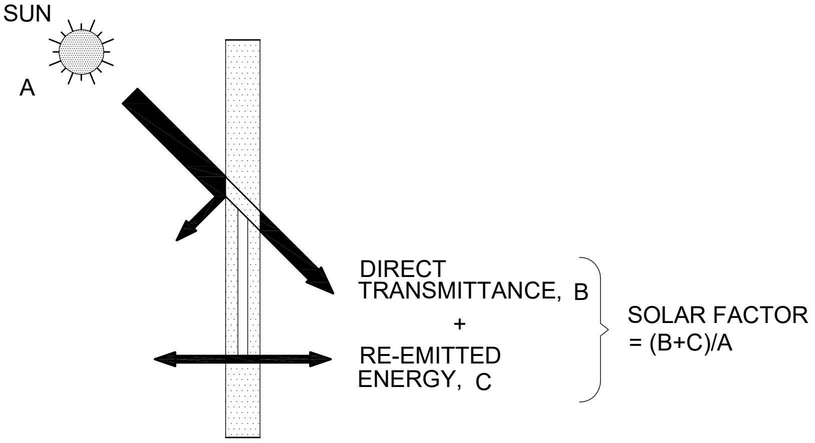


FIG. 1 SOLAR HEAT GAIN COEFFICIENT

b) Reflected part, $\rho_e\varphi_e$; and

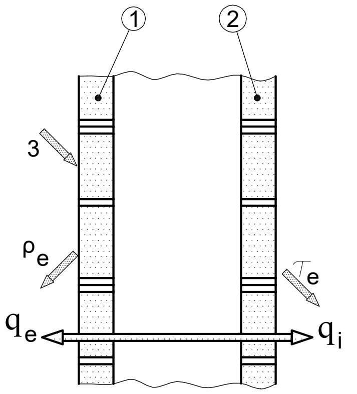
c) Absorbed part, $\alpha_e\varphi_e$;

where

T_e = solar direct transmittance,

ρ_e = solar direct reflectance, and

α_e = solar direct absorptance.



KEY :
1 OUTER PANE
2 SECOND INNER PANE
3 UNIT INCIDENT RADIANT FLUX
ρ_e = 0.38; q_e = 0.17;
T_e = 0.41; q_i = 0.04; therefore g = 0.45

FIG. 2 COMPONENTS OF INCIDENT SOLAR RADIANT FLUX

The relationship between the three characteristics is:

$$\tau_e + \rho_e + \alpha_e = 1$$

The absorbed part $\alpha_e\varphi_e$ is subsequently divided into two parts $q_i\varphi_e$ and $q_e\varphi_e$, which are energy transferred to the inside and outside respectively:

$$\alpha_e = q_i + q_e$$

where

q_i = secondary heat transfer factor of the glazing towards the inside; and

q_e = secondary heat transfer factor of the glazing towards the outside.

7.3 *Solar Direct Transmittance*

The solar direct transmittance τ_e of glazing shall be calculated using the following formula:

$$\tau_e = \frac{\sum\limits_{\lambda = 300\text{ nm}}^{2\,500\text{ nm}} \tau(\lambda) S_\lambda \,\Delta\lambda}{\sum\limits_{\lambda = 300\text{ nm}}^{2\,500\text{ nm}} S_\lambda \Delta\lambda}$$

where,

S_λ = relative spectral distribution of the solar radiation;

$\tau(\lambda)$ = spectral transmittance of the glazing; and

$\Delta\lambda$ = integration procedure are the same as in **5.1.11.4** except that the data points shall be chosen at the wavelengths given in Table 5.

7.4 Solar Direct Reflectance

The solar direct reflectance ρ_e of the glazing shall be calculated using the following formula:

$$\rho_e = \frac{\sum\limits_{\lambda = 300\text{ nm}}^{2\,500\text{ nm}} \rho_o(\lambda) S_\lambda \,\Delta\lambda}{\sum\limits_{\lambda = 300\text{ nm}}^{2\,500\text{ nm}} S_\lambda \Delta\lambda}$$

where,

S_λ = relative spectral distribution of the solar radiation (*see* **7.3**);

$\rho_o(\lambda)$ = spectral external reflectance of the glazing; and

$\Delta\lambda$ = integration procedure are the same as in **5.11.4** except that the data points shall be chosen at the wavelengths given in Table 5.

In the case of multiple glazing, the spectral external reflectance $\rho_o(\lambda)$ is calculated in accordance with **6.1**.

Table 5 Normalized Relative Spectral Distribution of Global Solar Radiation

(*Clauses* 7.3, 7.4, 7.6.3 *and* 7.6.4)

λ nm (1)	$S_\lambda\Delta\lambda$ (2)
300	0
305	0.000 057
310	0.000 236
315	0.000 554
320	0.000 916
325	0.001 309
330	0.001 914
335	0.002 018
340	0.002 189
345	0.000 260
350	0.002 445
355	0.002 555
360	0.002 683
365	0.003020
370	0.003 359

Table 5 (*Continued*)

λ nm (1)	$S_\lambda \Delta\lambda$ (2)
375	0.003 509
380	0.003 600
385	0.003 529
390	0.003 551
395	0.004 294
400	0.007 812
410	0.011 638
420	0.011 877
430	0.011 347
440	0.013 245
450	0.015 343
460	0.016 166
470	0.016 178
480	0.016 402
490	0.015 794
500	0.015 801
510	0.015 973
520	0.015 357
530	0.015 857
540	0.015 827
550	0.015 844
560	0.015 590
570	0.015 255
580	0.014 745
590	0.014 330
600	0.014 663
610	0.015 030
620	0.014 859
630	0.014 622
640	0.014 526
650	0.014 445
660	0.014 313
670	0.014 023
680	0.012 838
690	0.011 788
700	0.012 453
710	0.012 798
720	0.010 589
730	0.011 233
740	0.012 175
750	0.012 181

Table 5 (*Concluded*)

λ nm (1)	$S_\lambda \Delta\lambda$ (2)
760	0.009 515
770	0.010 479
780	0.011 381
790	0.011 262
800	0.026 718
850	0.048 240
900	0.040 297
950	0.021 384
1 000	0.036 097
1 050	0.034 110
1 100	0.018 861
1 150	0.013 228
1 200	0.022 551
1 250	0.023 376
1 300	0.017 756
1 350	0.003 743
1 400	0.000 741
1 450	0.003 792
1 500	0.009 693
1 550	0.013 693
1 600	0.012 203
1 650	0.010 615
1 700	0.007 255
1 750	0.007 183
1 800	0.002 157
1 850	0.000 395
1 900	0.000 082
1 950	0.001 087
2 000	0.003 024
2 050	0.003 988
2 100	0.004 229
2 150	0.004 142
2 200	0.003 690
2 250	0.003 592
2 300	0.003 436
2 350	0.003 163
2 400	0.002 233
2 450	0.001 202
2 500	0.000 475

NOTE — The values in this table are calculated according to the trapezoidal rule.

7.5 Solar Direct Absorptance

The solar direct absorptance α_e shall be calculated from the following formula:

$$\tau_e + \rho_e + \alpha_e = 1$$

7.6 Secondary Heat Transfer Factor Towards the Inside

7.6.1 *Boundary Conditions*

For the calculation of the secondary heat transfer factor towards the inside, q_i, the heat transfer coefficients of the glazing towards the outside, h_e, and towards the inside, h_i, are needed. These values mainly depend on the position of the glazing, wind velocity, inside and outside temperatures and, furthermore, on the temperature of the two external glazing surfaces.

As the purpose of this standard is to provide basic information on the performance of glazing, the following conventional conditions have been stated for simplicity:

a) Position of the glazing: vertical;
b) Outside surface: wind velocity approximately 4 m/s; corrected emissivity 0.837;
c) Inside surface: natural convection; emissivity optional; and
d) Air spaces are unventilated.

Under these conventional, average conditions, standard values for h_e and h_i are obtained:

$$h_e = 23 \text{ W/(m}^2\text{K)}$$

$$h_i = \left(3.6 + \frac{4.4\varepsilon_i}{0.837}\right) \text{W/m}^2 K$$

where

ε_i = corrected emissivity of the inside surface [for soda lime glass, $\varepsilon_i = 0.837$ and $h_i = 8$ W/(m^{2}K)].

If other boundary conditions are used to meet special requirements they shall be stated in the test report.

Values for ε_i lower than 0.837 (due to surface coatings with higher reflectance in the far infrared) should only to be taken into account if condensation on the coated surface can be excluded.

7.6.2 *Single Glazing*

The secondary heat transfer factor towards the inside, q_i, of single glazing shall be calculated using the following formula:

$$q_i = \alpha_e \frac{h_i}{h_e + h_i}$$

where

α_e = solar direct absorptance in accordance with **7.2;** and

h_e, h_i = heat transfer coefficients towards the outside and inside, respectively, in accordance with **7.6.1.**

7.6.3 *Double Glazing*

The secondary heat transfer factor towards the inside, q_i, of double glazing shall be calculated using the following formula:

$$q_i = \frac{\left(\dfrac{\alpha_{e1} + \alpha_{e2}}{h_e} + \dfrac{\alpha_{e2}}{\Lambda}\right)}{\left(\dfrac{1}{\text{h}_i} + \dfrac{1}{h_e} + \dfrac{1}{\Lambda}\right)}$$

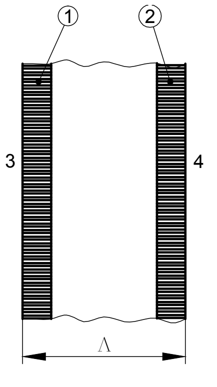
where

α_{e1} = solar direct absorptance of the outer (first) pane within the double glazing;

α_{e2} = solar direct absorptance of the second pane within the double glazing;

Λ = thermal conductance between the outer surface and the innermost surface of the double glazing (*see* Fig. 3), in watts per square metre per Kelvin (W/m^2.K); and

h_e, h_i = heat transfer coefficients towards the outside and the inside, respectively in accordance with **7.6.1**.



KEY :
1 PANE 1
2 PANE 2
3 OUTSIDE
4 INSIDE

FIG. 3 ILLUSTRATION OF THE MEANING OF THERMAL CONDUCTANCE, Λ

Characteristics α_{e1} and α_{e2} are calculated as follows:

$$\alpha_{e1} = \frac{\sum\limits_{\lambda=300\,\text{nm}}^{2\,500\,\text{nm}} \left\{ \alpha_1(\lambda) + \frac{\alpha_1'(\lambda)\tau_1(\lambda)\rho_2(\lambda)}{1-\rho_1'(\lambda)\rho_2(\lambda)} \right\} S_\lambda \Delta\lambda}{\sum\limits_{\lambda=300\,\text{nm}}^{2\,500\,\text{nm}} S_\lambda \Delta\lambda}$$

$$\alpha_{e2} = \frac{\sum\limits_{\lambda=300\,\text{nm}}^{2\,500\,\text{nm}} \left\{ \frac{\alpha_2(\lambda)\tau_1(\lambda)}{1-\rho_1'(\lambda)\rho_2(\lambda)} \right\} S_\lambda \Delta\lambda}{\sum\limits_{\lambda=300\,\text{nm}}^{2\,500\,\text{nm}} S_\lambda \Delta\lambda}$$

where

$\tau_1(\lambda)$, $\tau_2(\lambda)$, $\rho_1(\lambda)$, $\rho'_1(\lambda)$ and $\rho_2(\lambda)$ are as defined in **5.11.4**.

$\alpha_1(\lambda)$ = spectral direct absorptance of the outer pane, measured in the direction of the incident radiation, given by the relationship:

$$\alpha_1(\lambda) = 1 - \tau_1(\lambda) - \rho_1(\lambda)$$

$\alpha'_1(\lambda)$ = spectral direct absorptance of the outer pane, measured in the opposite direction to the incident radiation, given by the relationship:

$$\alpha_1'(\lambda) = 1 - \tau_1(\lambda) - \rho'_1(\lambda)$$

$\alpha_2(\lambda)$ = spectral direct absorptance of the second pane, measured in the direction of the incident radiation, given by the relationship:

$$\alpha_2(\lambda) = 1 - \tau_2(\lambda) - \rho_2(\lambda)$$

$\Delta\lambda$ and the integration procedure are the same as in **5.11.4** except that the data points shall be chosen at the wavelengths given in Table 5.

The thermal conductance Λ shall be determined for a temperature difference of ΔT = 15°C across the sample and a mean temperature of the sample of 10°C, or by measuring methods using the standard guarded hot plate method, or the standard heat flow metre method.

If another temperature difference ΔT across the sample and/or another mean temperature of the sample is used for the determination of the thermal conductance Λ to meet special requirements, this shall be stated in the test report.

7.6.4 *Multiple Glazing with n > 2 Components*

The secondary heat transfer factor towards the inside, q_i, of a multiple glazing with more than two components shall be calculated using the following formula:

where

α_{e1} = solar direct absorptance of the outer (first) pane within the *n*-fold glazing;

α_{e2} = solar direct absorptance of the second pane within the *n*-fold glazing;

α_{en} = solar direct absorptance of the n^{th} (inner) pane of the *n*-fold glazing;

h_e, h_i = heat transfer coefficients towards the outside and towards the inside respectively in accordance with **6.6.1**;

Λ_{12} = thermal conductance between the outer surface of the outer (first) pane and the centre of the second pane (*see* Fig. 4);

Λ_{23} = thermal conductance between the centre of the second pane and the centre of the third pane (*see* Fig. 9);

$\Lambda_{(n-1)n}$ = thermal conductance between the centre of the $(n-1)^{th}$ pane and the outer surface of the n^{th} (inner) pane (*see* Fig. 4); and

The thermal conductances Λ_{12}, Λ_{23}……..$\Lambda_{(n-1)n}$ shall be determined by iteration technique. The calculation of the direct solar absorptances α_{e1}, α_{e2},...α_{en} shall be performed using the methods given in **6.6.3**.

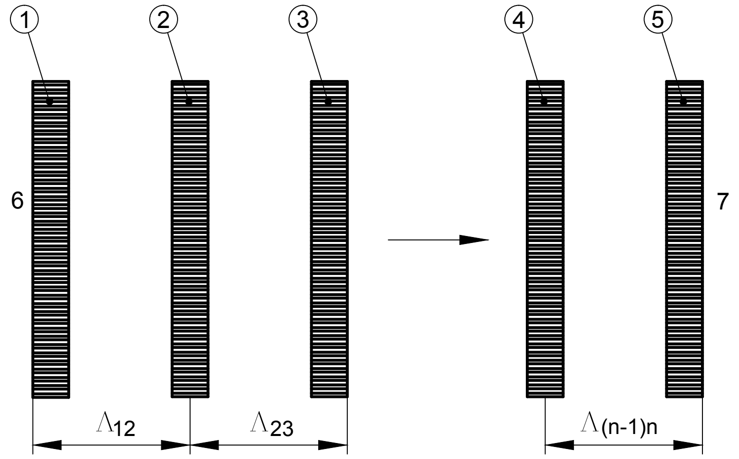
As an example for the calculation of the direct solar absorptances the following procedure is given which consist of the following (*n*-1) steps for a glazing consisting of *n* components:

a) *First step* — calculate the spectral characteristics of a unit consisting of (*n*-1) components 2,3,.......*n* according to what has been prescribed in **6.11.4** and **6.1**. Then combine this unit with the first (outer) pane as a double glazing.

b) *Second step* — calculate the spectral characteristics of a unit consisting of the (*n*-2) components 3,....,*n* and furthermore, those of a double glazing consisting of pane 1 and pane 2. These units are then combined as a double glazing. The sum α_{e1} + α_{e2} is then obtained. This procedure is continued up to the last $(n\text{-}1)^{th}$ step.

c) *$(n\text{-}1)^{th}$ step* — combine the (*n*-1) panes 1,2,... (*n*-1) and determine the spectral characteristics of this unit. This unit is then combined with the n^{th} (inner) pane as a double glazing. From the second equation in **7.6.3**, the sum α_{e1}, α_{e2} ...$\alpha_{e(n-1)}$ is obtained, that is with the known values $\alpha_{e1,}$ $\alpha_{e2,\ldots}$ $\alpha_{e(n-2)}$ from the previous steps $\alpha_{e(n-1)}$ is determined. α_{en} is obtained according to the expression of α_{e2} in **7.6.3**.

$$q_i = \frac{\frac{\alpha_{e1}+\alpha_{e2}+\alpha_{e3}+\ldots+\alpha_{en}}{h_e} + \frac{\alpha_{e2}+\alpha_{e3}+\ldots+\alpha_{en}}{\Lambda_{12}} + \frac{\alpha_{e3}+\ldots+\alpha_{en}}{\Lambda_{23}} + \ldots + \frac{\alpha_{en}}{\Lambda_{(n-1)n}}}{\frac{1}{h_i}+\frac{1}{h_e}+\frac{1}{\Lambda_{12}}+\frac{1}{\Lambda_{23}}+\ldots+\frac{1}{\Lambda_{(n-1)n}}}$$



KEY :

1 PANE 1
2 PANE 2
3 PANE 3
4 PANE (n - 1)
5 PANE n
6 OUTSIDE
7 INSIDE

NOTE: For triple glazing, pane 3 corresponds to pane n

FIG. 4 ILLUSTRATION OF THE MEANING OF THE THERMAL CONDUCTANCE $\Lambda_{12}, \Lambda_{23} \ldots\ldots\ldots \Lambda_{(n-1)n}$

In the case of triple glazing for the solar absorptances α_{e1}, α_{e2} and α_{e3} as a function of the spectral characteristics of the individual components of the unit, the following formulae are obtained:

$$\alpha_{e1} = \frac{\sum\limits_{\lambda = 300\,\text{nm}}^{2\,500\,\text{nm}} \left\{ \alpha_1(\lambda) + \frac{\tau_1(\lambda)\alpha_1'(\lambda)\rho_2(\lambda)\left[1-\rho_2'(\lambda)\rho_3(\lambda)\right] + \tau_1(\lambda)\tau_2^2(\lambda)\alpha_1'(\lambda)\rho_3(\lambda)}{\left[1-\rho_1'(\lambda)\rho_2(\lambda)\right]\cdot\left[1-\rho_2'(\lambda)\rho_3(\lambda)\right] - \tau_2^2(\lambda)\rho_1'(\lambda)\rho_3(\lambda)} \right\} S_\lambda \Delta\lambda}{\sum\limits_{\lambda = 300\,\text{nm}}^{2\,500\,\text{nm}} S_\lambda \Delta\lambda}$$

$$\alpha_{e2} = \frac{\sum\limits_{\lambda = 300\,\text{nm}}^{2\,500\,\text{nm}} \left\{ \frac{\tau_1(\lambda)\alpha_2(\lambda)\left[1-\rho_2'(\lambda)\rho_3(\lambda)\right] + \tau_1(\lambda)\tau_2(\lambda)\alpha_2'(\lambda)\rho_3(\lambda)}{\left[1-\rho_1'(\lambda)\rho_2(\lambda)\right]\cdot\left[1-\rho_2'(\lambda)\rho_3(\lambda)\right] - \tau_2^2(\lambda)\rho_1'(\lambda)\rho_3(\lambda)} \right\} S_\lambda \Delta\lambda}{\sum\limits_{\lambda = 300\,\text{nm}}^{2\,500\,\text{nm}} S_\lambda \Delta\lambda}$$

$$\alpha_{e3} = \frac{\sum\limits_{\lambda = 300\,\text{nm}}^{2\,500\,\text{nm}} \left\{ \frac{\tau_1(\lambda)\tau_2(\lambda)\alpha_3(\lambda)}{\left[1-\rho_1'(\lambda)\rho_2(\lambda)\right]\cdot\left[1-\rho_2'(\lambda)\rho_3(\lambda)\right] - \tau_2^2(\lambda)\rho_1'(\lambda)\rho_3(\lambda)} \right\} S_\lambda \Delta\lambda}{\sum\limits_{\lambda = 300\,\text{nm}}^{2\,500\,\text{nm}} S_\lambda \Delta\lambda}$$

where

$\tau_1(\lambda)$, $\tau_2(\lambda)$, $\tau_3(\lambda)$, $\rho_1(\lambda)$, $\rho'_1(\lambda)$, $\rho_2(\lambda)$, $\rho'_2(\lambda)$, $\rho_3(\lambda)$ are as defined in **5.11.4**;

$\alpha_1(\lambda)$, $\alpha'_1(\lambda)$ and $\alpha_2(\lambda)$ are as defined in **7.6.3** double glazing;

$\alpha'_2(\lambda)$ = spectral direct absorptance of the second pane, measured in the opposite direction to the incident radiation, given by the relationship:

$$\alpha'_2(\lambda) = 1 - \tau_2(\lambda) - \rho'_2(\lambda)$$

$\alpha_3(\lambda)$ = spectral direct absorptance of the third pane, measured in the direction of the incident radiation, given by the relationship:

$$\alpha_3(\lambda) = 1 - \tau_3(\lambda) - \rho_3(\lambda)$$

$\Delta\lambda$ and the integration procedure are the same as in **5.11.4** except that the data points shall be chosen at the wavelengths given in Table 5.

For a glazing with more than three components, the formulae for the solar absorptancesα_{e1}, α_{e2},..., α_{en} as a function of the individual components.

7.6.5 *Mean Radiant Temperature (MRT)*

MRT can be calculated by various methods, among which measuring with globe thermometer is the most common and is given by:

$$MRT = \sqrt[4]{T_g^4 + \frac{h_{cg}}{\varepsilon_g \sigma}(T_g - T_a)^4}$$

where

T_a = air temperature, in Kelvin;

T_g = black globe temperature, in Kelvin;

ε_g = emissivity of black globe;

σ = Stefane-Boltzmann constant; and

h_{cg} = convective heat transfer coefficient of the black globe.

8 TOTAL SOLAR ENERGY TRANSMISSION

8.1 The total solar energy transmitted into the room per unit area of glazing φ_{ei} is given by the relationship:

$$\varphi_{ei} = \varphi_e g$$

where

φ_{ei} = incident solar radiation flux per unit area;

g = total solar energy transmittance of the glazing; and

φ_e = values can be obtained from appropriate tables in meteorological literature.

NOTE — The solar heat gain co-efficient/solar factor (SHGC/SF) requirement for the glazing should be selected based on the prescriptive requirements are mentioned in Annex B.

8.2 Additional Heat Transfer

If the room temperature T_i differs from the outside temperature T_o, an additional heat transfer occurs in addition to φ_{ei}. This additional heat flow q_z can be calculated as follows:

$$q_z = U(T_o - T_i)$$

where, U is the U-value (thermal transmittance) of glazing.

9 UV-TRANSMITTANCE

The UV-transmittance of glazing is the fraction of the incident solar radiation transmitted by the glazing in the 300 nm to 380 nm range (UV-B range from 300 nm to 315 nm and UV-A range from 315 nm to 380 nm). The UV-transmittance τ_{UV} is calculated as follows:

$$\tau_{UV} = \frac{\sum_{\lambda = 300\text{ nm}}^{380\text{ nm}} \tau(\lambda) S_\lambda \Delta\lambda}{\sum_{\lambda = 300\text{ nm}}^{380\text{ nm}} S_\lambda \Delta\lambda}$$

where

S_λ = relative spectral distribution of UV-radiation;

$\tau(\lambda)$ = spectral transmittance of the glazing; and

$\Delta\lambda$ and the integration procedure are the same as **5.11.4** except that the data points shall be chosen at the wavelength given in Table 6.

Table 6 Normalized Relative Spectral Distribution of Global Solar Radiation

(*Clause* 9)

Sl No.	λ nm	$S_\lambda\Delta\lambda$
(1)	(2)	(3)
i)	300	0
ii)	305	0.001 859
iii)	310	0.007 665
iv)	315	0.017 961
v)	320	0.029 732
vi)	325	0.042 466
vii)	330	0.062 108
viii)	335	0.065 462
ix)	340	0.071020
x)	345	0.073 326
xi)	350	0.079 330
xii)	355	0.082 894
xiii)	360	0.087 039
xiv)	365	0.097 963
xv)	370	0.108 987
xvi)	375	0.113 837
xvii)	380	0.058 351

NOTE — The values in this table are calculated according to the trapezoidal rule.

This average extends over the defined UV-portion of the solar spectrum. It may not be correlated with solar radiation damage of materials and skin.

10 *U*-VALUE

Heat transmittance through a surface by conduction, convection, and radiation is expressed by its *U*-value. *U*-value is the amount of heat transferred that is lost or gained due to a temperature differential of 1 K through 1 m^2. The rate of heat transfer (*U*-value) is minimized by the use of double glazing, using gas inside cavity or by using low-E glass for inside pane of double glazed unit.

The *U*-value requirement for the glazing system should be selected in accordance with the Table 7 and Annex B.

Table 7 Thermal Performance of Different Glass Shading Devices

(*Clause* 10)

Sl No. (1)	Name of the Shading Device (2)	Transmittance, *U*-Value (3)	Shade Factor (4)
i)	Plain glass sheet (3.0 mm thick)	5.23	1.00
ii)	Plain glass + Wire mesh outside	5.00	0.65
iii)	Painted glass:		
	a) White paint	5.22	0.35
	b) Yellow paint	5.22	0.37
	c) Green paint	5.22	0.40
iv)	Heat absorbing glass	4.65	0.45
v)	Plain glass sheet + Venetian blind inside:		
	a) Light colour	3.14	0.35
	b) Dark colour		0.40
vi)	Plain glass sheet which is:		
	a) 100 percent shaded	5.23	0.14
	b) 75 percent shaded		0.34
	c) 60 percent shaded		0.56

NOTE — Indicative values, actual value of the system to be measured using either approved simulation software or testing laboratory.

ANNEX A

(*Clause* 2)

LIST OF REFERRED INDIAN STANDARDS

IS No.	*Title*
2553 (Part 1) : 1990	Specification for safety glass: Part 1 General purpose (*third revision*)
16231	Use of glass in buildings — Code of practice:
(Part 1) : 2018	General methodology for selection (*first revision*)
(Part 3) : 2018	Fire and loading (*first revision*)
(Part 4) : 2018	Safety related to human impact (*first revision*)
14900 : 2018	Specification for transparent float glass (*first revision*)

ANNEX B

(*Clauses* 5.1, 8 and 10)

MINIMUM PERFORMANCE REQUIREMENT OF GLAZING FOR EXTERIORS

B-1 The panel size design of the exterior glass for the building is done in accordance with this standard considering the effect due to wind load, other imposed load, seismic design [as per IS 16231 (Part 3)]. The type of glazing to be installed is determined considering human safety in accordance with IS 16231 (Part 4).

In the determination of the energy and thermal performance of the glazing, the three compliance approaches prescriptive in nature, defines the minimum glazing/glazing system requirement to be met.

The prescriptive values are specified with respect to the geographic climatic zone and glazing area of the building.

B-2 BUILDING FENESTRATIONS

The fenestration shall comply with the maximum glazing area weighted on *U*-value and solar factor as given in Table 8.

The window wall ratio (WWR) is defined by the total fenestration area to the total gross area of the building envelope which is limited to 70 percent. The corresponding minimum visible light transmission is given below. For fenestration area greater than 70 percent, *see* other specialist literatures:

WWR	*Minimum Visible Light Transmission* Percent
0 – 0.3	27
0.31 – 0.4	20
0.41 – 0.5	16
0.51 – 0.6	13
0.61 – 0.7	11

B-3 WEATHER PERFORMANCE

Air infiltration from the fix areas shall be permitted to be within 1.5 $m^3/h.m^2$ and for operable sashes, shall be within 2 $m^3/h.m^2$.

Water should be contained in the gutter and drained back to the exterior. Any uncontrolled water in excess of 15 ml or more on the top surface of any exposed interior shall be considered as leakage.

Table 8 *U*-Value Requirement for Glazing System

(*Clause* B-2)

Sl No.	**Climate**	**Maximum *U*-Value** W/m^{2}K	**Maximum SHGC**	
			WWR ≤ 40 percent	40 percent < WWR ≤ 60 percent
(1)	(2)	(3)	(4)	(5)
i)	Composite	3.30	0.25	0.20
ii)	Hot and dry	3.30	0.25	0.20
iii)	Warm and humid	3.30	0.25	0.20
iv)	Moderate	6.90	0.40	0.30
v)	Cold	3.30	0.51	0.51

ANNEX C

[*Clause* 5.2.4.2 (c)]

TEST REQUIREMENTS FOR COATED GLASS

C-1 The coated glass that is used for the exterior building of commercial and non-commercial (residential building) should meet the test requirement listed in this annex.

C-2 MEASUREMENTS OF PERFORMANCE

The performance factors and spectral details of the coated glass shall be determined using standard accepted spectrophotometer equipment. The actual size shall be dependent on the type of equipment being used for the measurements. The transmittance of the measurement sample shall be measured with radiation of normal incidence at the following wavelengths:

a) 550 nm (representative wavelength for light and solar transmittance); and
b) 900 nm (representative wavelength for solar transmittance).

For glass claiming to have a low emissivity coating, a measurement of the reflectance shall be made at 8 µm using radiation of nearly normal incidence.

C-3 CONDENSATION RESISTANCE TEST

C-3.1 This test consists of subjecting the coated glass to a water saturated atmosphere at constant temperature. The samples have condensation continually forming on them and it is this condensation that may cause surface degradation.

C-3.2 Test apparatus should have a provision of four test pieces and the materials used for the inner walls shall be corrosion resistant and shall not affect the test pieces.

C-3.3 Procedure

a) The water tank shall be filled with demineralized water, having conductivity lower than 30 µS and a *p*H higher than 5. The internal temperature of the cabinet shall be controlled by means of a reference thermocouple keeping the temperature of the reference glass piece at 40 ± 1.5°C.
b) The test cabinet shall be in a room with an ambient temperature of 23 ± 3°C. Care shall be taken to ensure that draughts, dust, moisture and solar radiation do not interfere with the test cabinet.
c) The reference temperature shall be reached within 2 h of commencing heating. Condensation shall be seen to form on the glass pieces. The test is continued without interruption for the required time. Both the internal reference and the external air temperature shall be regularly checked.

C-3.4 Requirements

a) No defect, greater than 3 mm length.
b) Maximum one defect between 2 mm and 3 mm length.
c) Maximum five defects between 1 mm and 2 mm length.
d) No scratches, staining of the coating or clusters of pinholes greater than 1 mm.
e) When compared with the reference test piece, in both reflection and transmission, there shall be no significant colour change. This observation shall be made within20 s.
f) The transmittance measured at 550 nm and 900 nm shall differ by no more than ± 0.03 from the corresponding measured value on the reference test piece.

C-4 ACID RESISTANCE TEST

C-4.1 This test consists of subjecting the coated glass to a sulphur dioxide saturated atmosphere at constant temperature. The samples shall have condensation continually forming on them. It is this condensation together with the quantity of sulphur dioxide (SO_2) that may cause surface degradation. Test apparatus should have a provision of four test pieces and the material used for the inner walls shall be corrosion resistant and shall not affect the test pieces.

C-4.2 Procedure

a) The test cabinet contains 2 litre of demineralized water having conductivity lower than 30 µS. When the cabinet is closed, 0.2 litre of sulphur dioxide (SO_2) shall be added and the heating system switched on.
b) The test consists of a repetition of 24 h cycles (*see* Fig. 5).
c) Each cycle consists of high temperature plus condensation period and an ambient temperature without condensation period.
d) The temperature shall increase to 40 ± 1.5°C in less than 1.5 h. During the next 6.5 h the test pieces shall be subjected to condensation in the sulphur dioxide (SO_2) atmosphere.

C-4.3 Requirement

The transmittance measured at 550 nm and 900 nm shall differ by not more than ± 0.03 nm from the corresponding measured value on the reference test piece.

C-5 NEUTRAL SALT SPRAY

C-5.1 This test consists of subjecting the coated glass to neutral, water saline atmosphere at constant temperature. It is the water saline spray that may cause surface degradation.

Test apparatus should have a provision of four test pieces and the material used for the inner walls shall be corrosion resistant and shall not affect the test pieces.

C-5.2 Procedure

a) The test cabinet shall be prepared and run for a minimum period of 24 h before the test pieces are placed within it. The neutral salt solution is made up by dissolving sodium chloride (NaCl), in demineralized water having conductivity lower than 30 µS, to produce a concentration of 50 ± 5 g/l at 25 ± 2°C.

b) The compressed air supplied to the spray nozzle shall be passed through a filter to remove all traces of oil or solid matter and shall be at an absolute pressure of 70 kPa to 170 kPa through a saturator at 40 ± 1.5°C. The spray nozzle shall be made of inert material, with baffles to prevent direct impact of spray on the test pieces.

C-5.3 Requirements

a) No defect, greater than 3 mm length;

b) Maximum one defect between 2 mm and 3 mm length;

c) Maximum five defects between 1 mm and 2 mm length;

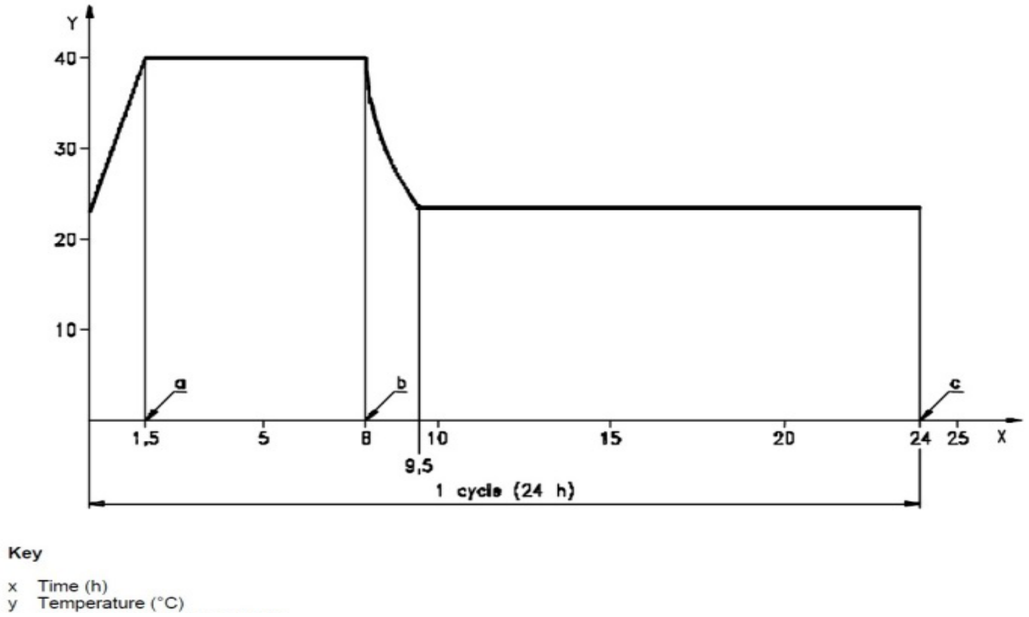
d) No scratches, staining of the coating or clusters of pinholes greater than 1 mm;

e) When compared with the reference test piece, in both reflection and transmission, there shall be no significant colour change. This observation shall be made within 20 s; and

f) The transmittance measured at 550 nm and 900 nm shall differ by no more than ± 0.03 nm from the corresponding measured value on the reference test piece.

C-6 ABRASION RESISTANCE TEST

C-6.1 This test consists of subjecting the coated surface of the coated glass to rubbing with a felt pad in dry condition. It is the type of pad, the loading on it and the number of strokes that may cause surface degradation.



NOTES

1 *a* = maximum time to reach 40°C.

2 *b* = cessation of heating the cabinet and ventilation of the cabinet.

3 *c* = solution removal rinsing of cabinet.

Fig. 5 Hour Cycle of Heating

C-6.2 Procedure

a) The metal finger shall be approximately 15 mm to 20 mm in diameter and shall be driven so as to produce a frequency of 60 strokes/min + 6 strokes/min alternating forwards and backwards. The stroke length shall be 120 ± 5 mm. The strokes shall be parallel and ensure a constant pressure over the zone to be tested.

b) A circle shape with a diameter of 14.5 ± 0.5 mm.

c) The test sequence shall commence within 30 min of the sample being cleaned.

d) The metal finger containing the felt pad shall be lowered on to the glass surface and a load of 4 N applied perpendicular to the glass surface *via* the felt pad.

C-6.3 Requirements

a) Ensure that the abraded area is uniform.

b) The transmittance measured at 550 nm and 900 nm shall differ by no more than ± 0.03 nm from the corresponding measured value on the reference test piece.

C-7 DURATION OF TESTS

The duration of tests shall be as per the following:

Sl No.	*Test*	*Test Duration for Class*		
		A	B	S
(1)	(2)	(3)	(4)	(5)
i)	Condensation resistance	21 days	4 days	14 days
ii)	Acid resistance	5 cycles	1 cycle	5 cycles
iii)	Neutral salt spray	21 days	10 days	—
iv)	Abrasion resistance	500 strokes	50 strokes	500 strokes

NOTES

1 *Class A* — The coated surface of the glass can be positioned on the outer or the inner face of the building.

2 *Class B* — The coated glass can be used as monolithic glazing but the coated surface shall be on the inner face of the building.

3 *Class S* — The coated surface of the glass can be positioned on the outer or the inner face of the building but these types of coated glasses can only be used in specifically defined applications.

ANNEX D

(*Foreword*)

COMMITTEE COMPOSITION

Building Construction Practices Sectional Committee, CED 13

Organization	*Representative(s)*
In Personal Capacity (*Flat No. 2061, Engineers Apartments, Plot 11, Sector - 18A, Dwarka, New Delhi* 110078)	Shri D. S. Sachdev (***Chairman***)
Ahluwalia Contracts (India) Limited, New Delhi	Shri Shobhit Uppal Shri Pradeep Kumar (*Alternate*)
Association of Consulting Civil Engineers (India), Bengaluru	Shri A. N. Prakash Shri Satish V. Salpekar (*Alternate*)
Bhabha Atomic Research Centre, Mumbai	Shri K. Srinivas Shri H. E. Iyer (*Alternate*)
Builders Association of India, New Delhi	Shri Surojit Samanta Shri Ram Avtar (*Alternate*)
Building Materials & Technology Promotion Council, New Delhi	Shri Chandi Nath Jha
Central Insecticides Board, Faridabad	Additional PPA cum Secretary (CIB & RC) Joint Director (Entomology) (*Alternate*)
Central Public Works Department, New Delhi	Chief Engineer (CSQ) Superintending Engineer (TAS) (*Alternate*)
Confederation of Construction Products and Services, New Delhi	Shri Deepak Gahlowt Shri Shashi Kant (*Alternate*)
CSIR-Central Building Research Institute, Roorkee	Shri S. K. Negi Dr Ajay Chourasia (*Alternate*)
CSIR-North East Institute of Science and Technology, Jorhat	Representative
CSIR-Structural Engineering Research Centre, Chennai	Director Dr P. Srinivasan (*Alternate*)
Delhi Development Authority, New Delhi	Chief Engineer (SZ) Superintending Engineer (P)-1 (*Alternate*)
Delhi Urban Shelter Improvement Board, New Delhi	Representative
Engineers India Limited, New Delhi	Shri Rajanji Srivastava Shri Ravindra Kumar (*Alternate*)
Forest Research Institute, Dehradun	Dr Kishan Kumar V. S.
Housing & Urban Development Corporation Limited, New Delhi	Representative
Indian Buildings Congress, New Delhi	Shri S. C. Bhatia Shri P. S. Chadha (*Alternate*)
Indian Pest Control Association, New Delhi	Vice President General Secretary (*Alternate*)
Indian Plywood Industries Research & Training Institute, Bengaluru	Shri Amitava Sil Shri Anand Nandanwar (*Alternate*)
Larsen & Toubro Limited, ECC Division, Chennai	Shri Rajan Venkateswaran Shri V. Sukumar Hebbar (*Alternate*)

Organization	*Representative(s)*
Military Engineer Services, Engineer-in-Chief's Branch, Integrated HQ of MoD, (Army), New Delhi	Jt DG (Architecture)
NBCC (India) Limited, New Delhi	Executive Director (Engg) General Manager (Engg) (*Alternate*)
NTPC Ltd, New Delhi	Shri R. L. Das Shri Anil Kapoor (*Alternate*)
Pest Control (India) Pvt Ltd, Mumbai	Shri Shankar M. Ghuge Shri Nitin B. Jagtap (*Alternate*)
Public Works Department, Govt of Gujarat, Gujarat	Superintending Engineer, Design (R&D)
Public Works Department, Govt of NCT of Delhi, New Delhi	Representative
Research, Designs and Standards Organization, Ministry of Railways, Lucknow	Director (Works) ADE (Works) (*Alternate*)
School of Planning & Architecture, New Delhi	Prof Anil Dewan Prof Jaya Kumar (*Alternate*)
The All India Glass Manufacturers' Federation, New Delhi	Shri Sourabh Kankar Shri Rupinder Shelly (*Alternate*)
The Energy and Resources Institute, New Delhi	Shri Sanjay Seth Ms Megha Behal (*Alternate*)
The Indian Institute of Architects, Mumbai	Shri Vijay Garg Shri Shamit Manchanda (*Alternate*)
The Institution of Engineers (India), Kolkata	Shri P. K. Adlakha Shri Devendra Gill (*Alternate*)
In personal capacity (*Pratap Nursery Lane Near Gurudwara, Panditwari, Dehradun*)	Shri K. S. Pruthi
BIS Directorate General	Shri Sanjay Pant, Scientist 'F' and Head (Civil Engineering) [Representing Director General (*Ex-officio*)]

Member Secretary

Shri S. Arun Kumar
Scientist 'D' (Civil Engineering), BIS

Panel for Use of Glass in Buildings, CED 13/P1

Organization	*Representative(s)*
In Personal Capacity (*Flat A2/16, Sri Agrasen Society, Sector 7, Dwarka, New Delhi* 110075)	Shri R. N. Dandekar (***Convener***)
Central Public Works Department, New Delhi	Chief Engineer (CSQ) Superintending Engineer (TAS) (*Alternate*)
Confederation of Construction Products and Services, New Delhi	Shri Deepak Gahlowt Shri Shashi Kant (*Alternate*)
CSIR-Central Building Research Institute, Roorkee	Dr Ashok Kumar
Glazing Society of India, Chennai	Shri Gohul Deepak Shri Subin Calvin Geo (*Alternate*)
Kuraray India Pvt Ltd, New Delhi	Shri Malvindersingh Roooprai

Organization	*Representative(s)*
NTPC Ltd, New Delhi	Shri Anil Kapoor
Saint-Gobain Glass India Ltd, Chennai	Shri A. R. Unnikrishnan Shri N. Murali (*Alternate*)
The All India Glass Manufacturers' Federation Association, New Delhi	Shri Somasundaram Senthil Shri Prem Dutt (*Alternate*)
The Energy Resources Institute, New Delhi	Shri Sanjay Seth
The Indian Institute of Architects, Mumbai	Shri Vijay Garg Shri Ashutosh Agarwal (*Alternate*)
The Institution of Engineers (India), New Delhi	Shri P. K. Adlakha

Bureau of Indian Standards

BIS is a statutory institution established under the *Bureau of Indian Standards Act*, 2016 to promote harmonious development of the activities of standardization, marking and quality certification of goods and attending to connected matters in the country.

Copyright

BIS has the copyright of all its publications. No part of these publications may be reproduced in any form without the prior permission in writing of BIS. This does not preclude the free use, in the course of implementing the standard, of necessary details, such as symbols and sizes, type or grade designations. Enquiries relating to copyright be addressed to the Director (Publications), BIS.

Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the latest issue of 'BIS Catalogue' and 'Standards: Monthly Additions'.

This Indian Standard has been developed from Doc No.: CED 13 (12374).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002
Telephones: 2323 0131, 2323 3375, 2323 9402 *Website*: www.bis.gov.in

Regional Offices: *Telephones*

Central : Manak Bhavan, 9 Bahadur Shah Zafar Marg
NEW DELHI 110002
{ 2323 7617, 2323 3841

Eastern : 1/14 C.I.T. Scheme VII M, V.I.P. Road, Kankurgachi
KOLKATA 700054
{ 2337 8499, 2337 8561, 2337 8626, 2337 9120

Northern : Plot No. 4-A, Sector 27-B, Madhya Marg
CHANDIGARH 160019
{ 265 0206, 265 0290

Southern : C.I.T. Campus, IV Cross Road, CHENNAI 600113
{ 2254 1216, 2254 1442, 2254 2519, 2254 2315

Western : Manakalaya, E9 MIDC, Marol, Andheri (East)
MUMBAI 400093
{ 2832 9295, 2832 7858, 2832 7891, 2832 7892

Branches : AHMEDABAD. BENGALURU. BHOPAL. BHUBANESHWAR. COIMBATORE. DEHRADUN. DURGAPUR. FARIDABAD. GHAZIABAD. GUWAHATI. HYDERABAD. JAIPUR. JAMMU. JAMSHEDPUR. KOCHI. LUCKNOW. NAGPUR. PARWANOO. PATNA. PUNE. RAIPUR. RAJKOT. VISAKHAPATNAM.

Published by BIS, New Delhi